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(54) Improvements in or relating to cellular mobile radio system

(57) A cellular mobile radio system, which is arranged to operate in accordance with a packet reservation multiple access protocol, wherein at least one time slot in each frame is designated for the transmission of access contention data which includes a field reserved for data specifying a number of information slots required by a mobile unit, and which system includes a base station adapted for operation such that consequent upon receipt of data in the said reserved field the base station is arranged to respond by allocating available slots to satisfy the requirement of the mobile unit.

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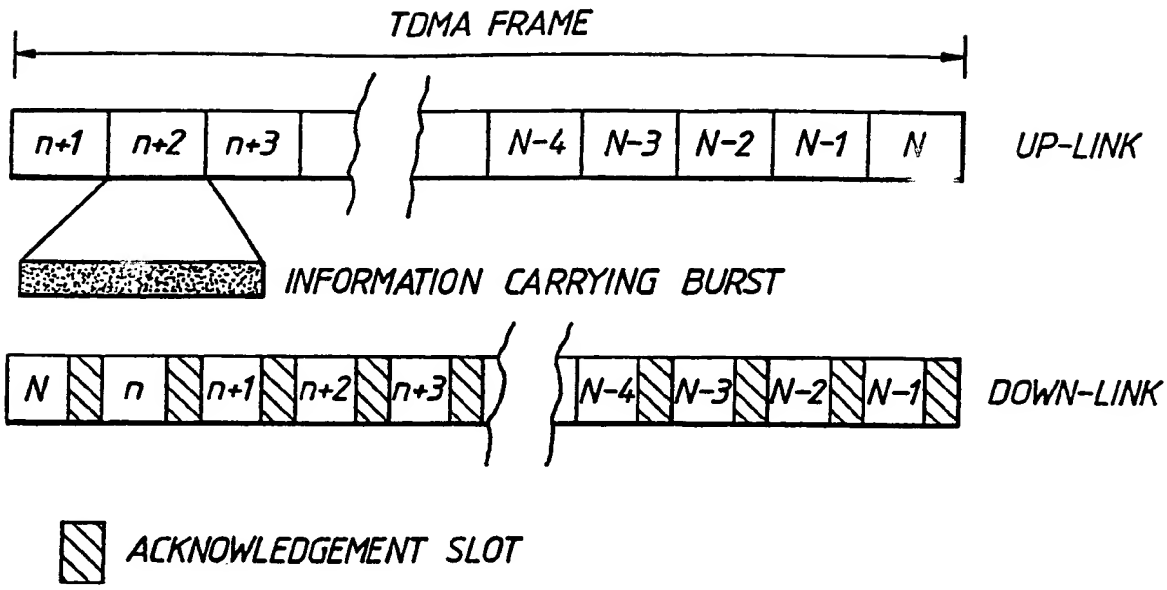
TDMA FRAME
n+1
n+2
n+3
N-4
N-3
N-2
N-1
N
UP-LINK
INFORMATION CARRYING BURST
N
n
n+1
n+2
n+3
N-4
N-3
N-2
N-1
DOWN-LINK
ACKNOWLEDGEMENT SLOT

Fig.1.

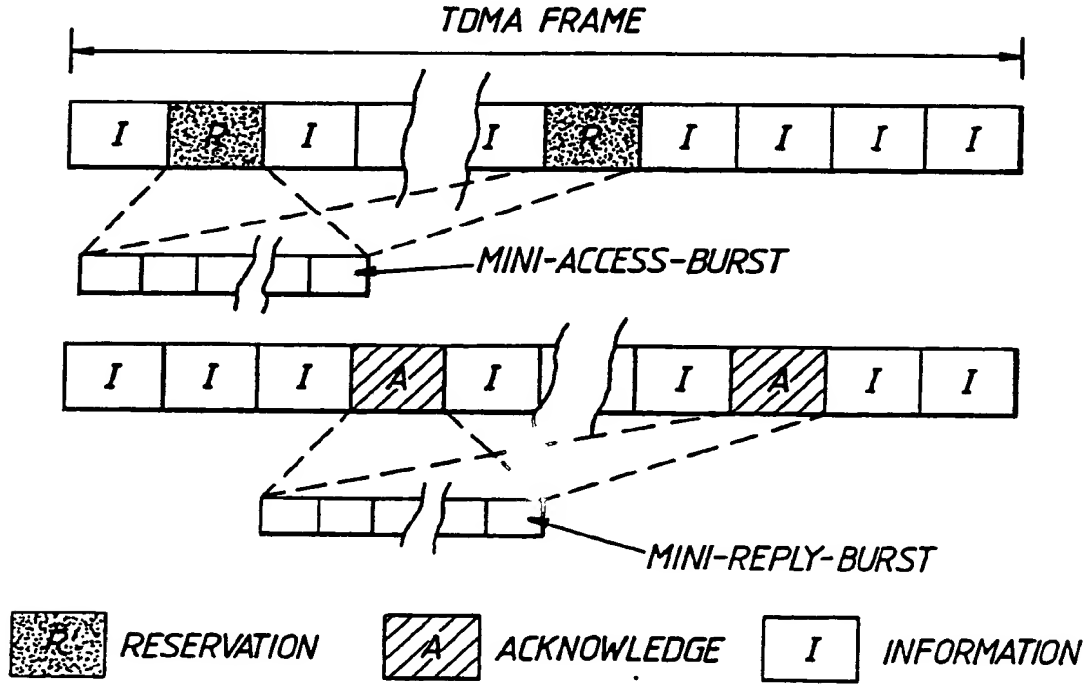
TDMA FRAME
I
R
I
I
R
I
I
I
I
MINI-ACCESS-BURST
I
I
I
A
I
I
A
I
I
MINI-REPLY-BURST
R
RESERVATION
A
ACKNOWLEDGE
I
INFORMATION

Fig.2.

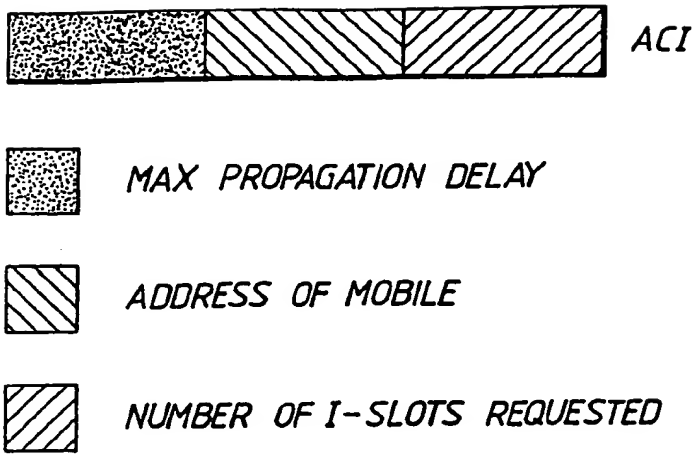
ACI
MAX PROPAGATION DELAY
ADDRESS OF MOBILE
NUMBER OF I-SLOTS REQUESTED

Fig.3.

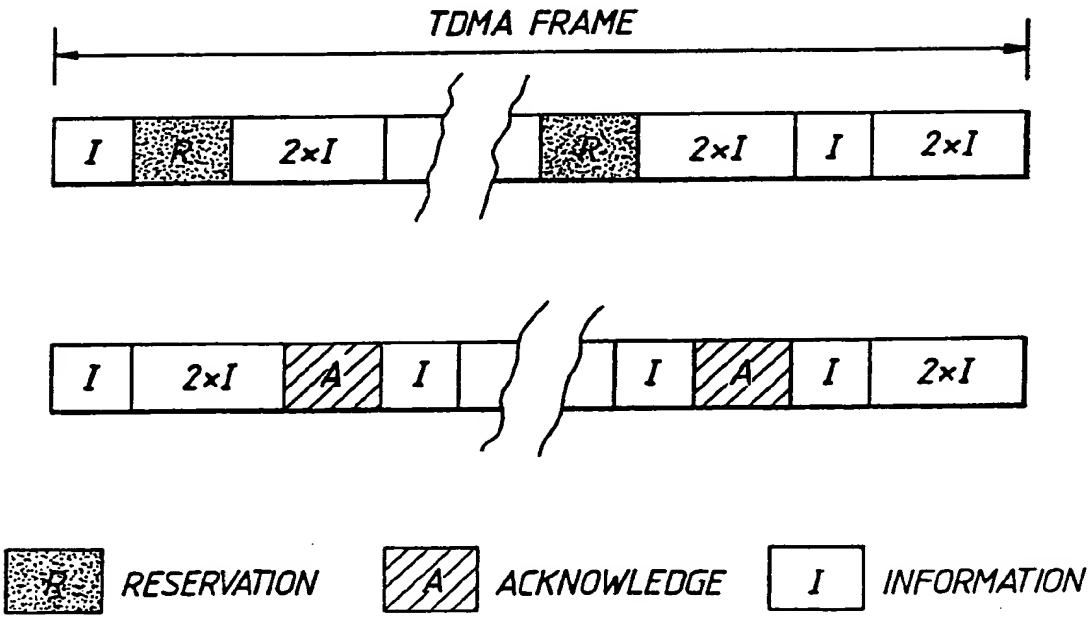
TDMA FRAME
I
R
2×I
I
2×I
A
RESERVATION
ACKNOWLEDGE
INFORMATION

Fig.4.

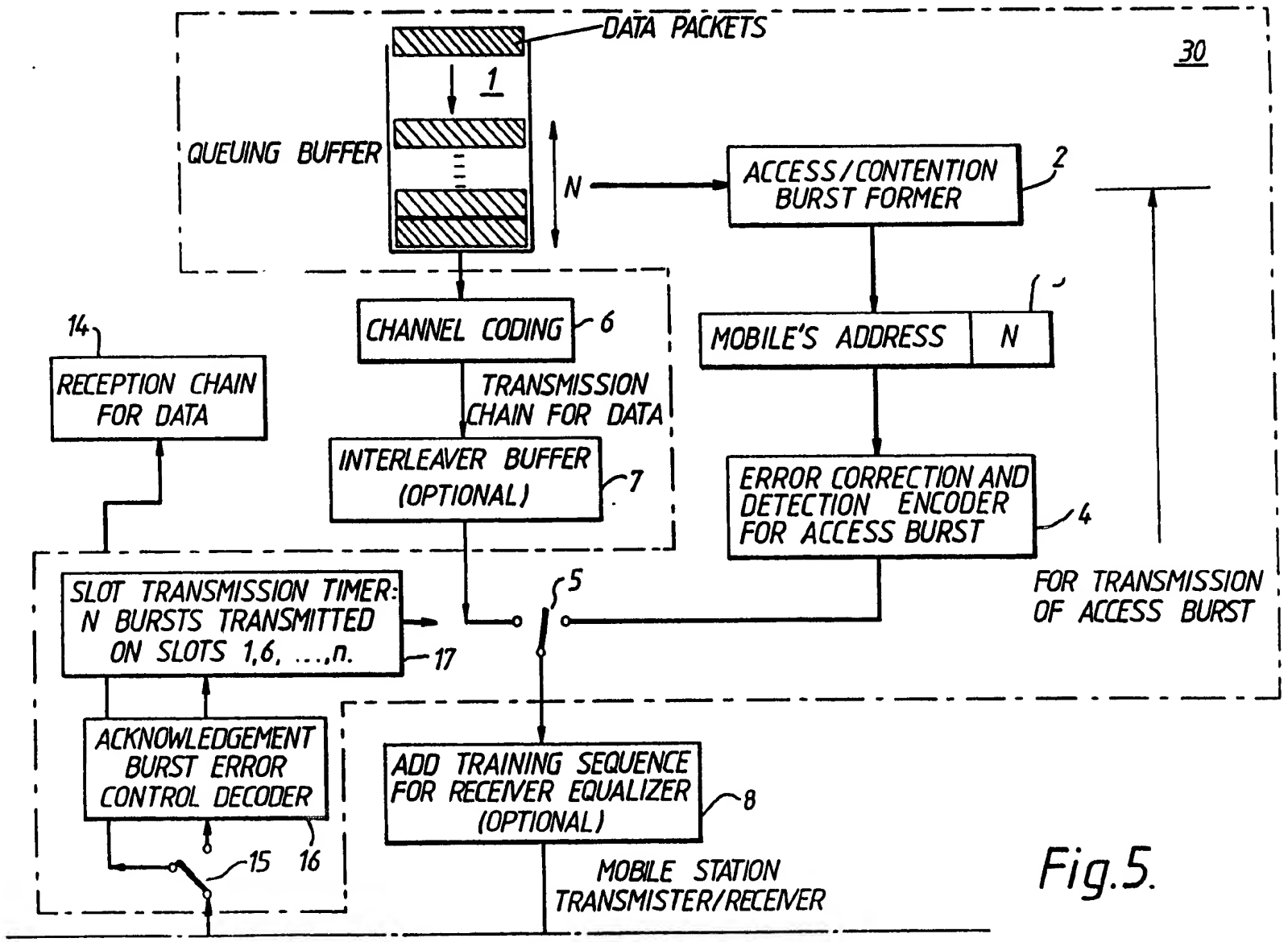
DATA PACKETS
30
1
QUEUING BUFFER
N
ACCESS/CONTENTION BURST FORMER
2
CHANNEL CODING
6
MOBILE'S ADDRESS
N
14
RECEPTION CHAIN FOR DATA
TRANSMISSION CHAIN FOR DATA
INTERLEAVER BUFFER (OPTIONAL)
7
ERROR CORRECTION AND DETECTION ENCODER FOR ACCESS BURST
4
5
SLOT TRANSMISSION TIMER: N BURSTS TRANSMITTED ON SLOTS 1,6, ...,n.
17
FOR TRANSMISSION OF ACCESS BURST
ACKNOWLEDGEMENT BURST ERROR CONTROL DECODER
ADD TRAINING SEQUENCE FOR RECEIVER EQUALIZER (OPTIONAL)
8
15
16
MOBILE STATION TRANSMISTER/RECEIVER

Fig.5.

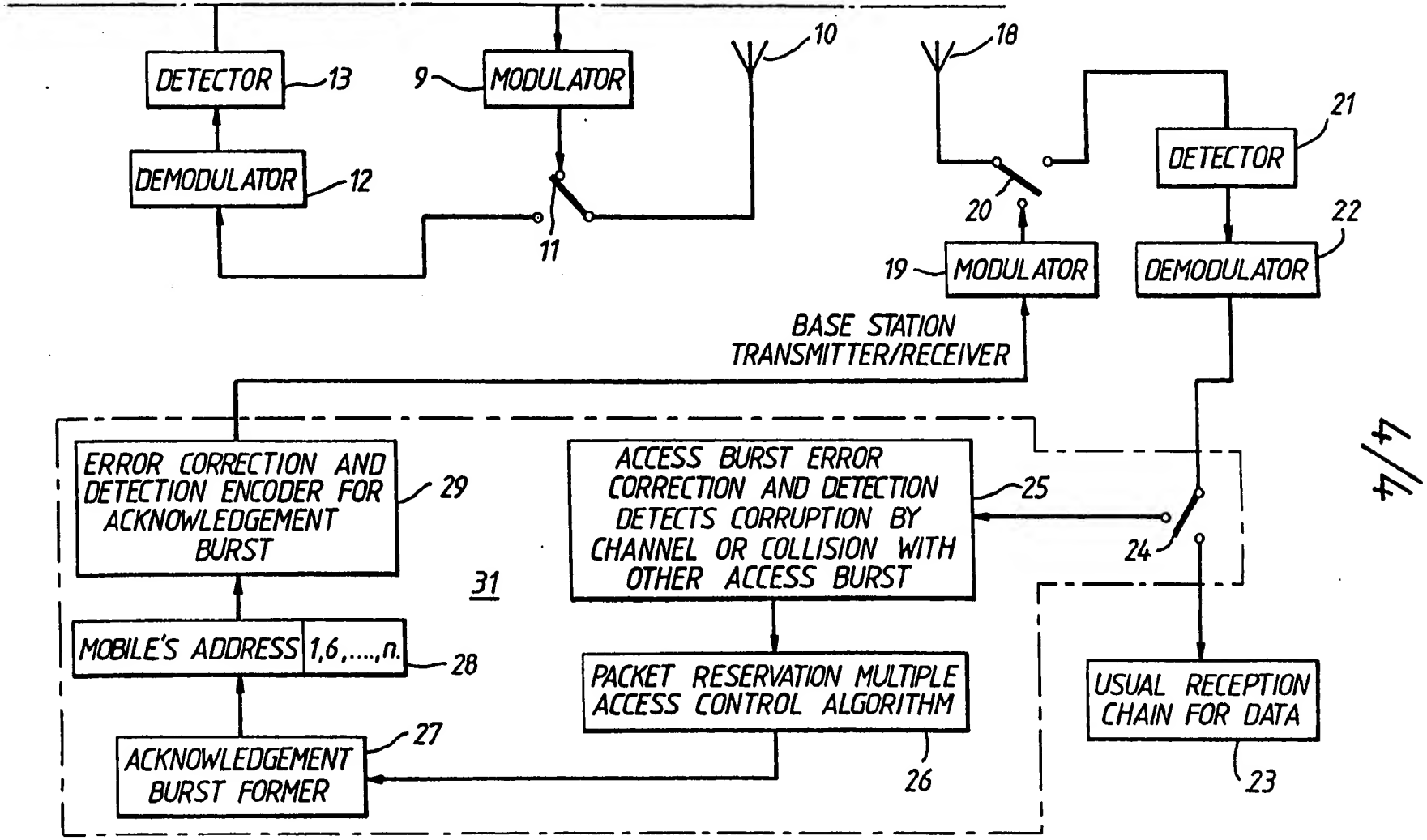
DETECTOR
13
9
MODULATOR
10
18
21
DEMODULATOR
12
11
20
DETECTOR
19
MODULATOR
DEMODULATOR
22
BASE STATION
TRANSMITTER/RECEIVER
ERROR CORRECTION AND DETECTION ENCODER FOR ACKNOWLEDGEMENT BURST
29
ACCESS BURST ERROR CORRECTION AND DETECTION DETECTS CORRUPTION BY CHANNEL OR COLLISION WITH OTHER ACCESS BURST
25
24
31
MOBILE'S ADDRESS
1,6,....,n.
28
PACKET RESERVATION MULTIPLE ACCESS CONTROL ALGORITHM
USUAL RECEPTION CHAIN FOR DATA
27
ACKNOWLEDGEMENT BURST FORMER
26
23
ELEMENTS TO IMPLEMENT VARIABLE BIT RATE MULTIPLE ACCESS

Fig.5 cont.

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IMPROVEMENTS IN OR RELATING TO CELLULAR MOBILE RADIO SYSTEMS

This invention relates to cellular mobile radio systems which include a packet reservation, multiple access (PRMA) protocol, and more especially it relates to the provision of a variable bit rate service for such systems.

It is envisaged that the provision of a variable bit rate service whereby a portion of the available channel capacity may be reserved on demand by a mobile user to permit the transmission of additional data, as may for example be required in a video link, will become increasingly important.

Systems in which user mobiles contend for access in the same time slot in which they transmit information are known and one such system is described in an article entitled 'Performance of PRMA: A packet voice protocol for cellular systems', which was published in IEEE Transactions on Vehicular Technology, vol.40 No. 3, August 1991, hereinafter referred to as Ref. 1. Such systems have the disadvantage that each mobile contends blindly for required access and therefore undue delays may occur in the presence of contention for the same time slot by two or more mobiles and quite obviously if a mobile requires a number of time slots there is a probability of even greater delays especially since each slot must be individually contended for.

In an alternative system as described in an article entitled 'A reservation multiple access protocol for microcellular mobile communication systems', which was published in IEEE Transactions on Vehicle Technology, volume 39, No. 4, November 1990,

hereinafter referred to as Ref. 2, contention/access data and information data are transmitted in separate time slots and moreover the arrangement is such that the base station can have a full knowledge of slot availability, which system is hereinafter referred to as a PRMA system of the kind specified.

In order efficiently to provide for variable bit rate transmission a user mobile must be able to reserve a plurality of slots in a given time frame. With known and presently proposed systems, this facility is not catered for.

It is an object of the present invention to provide a system wherein the reservation of a plurality of slots in a given time frame is facilitated.

According to the present invention as broadly conceived, a cellular mobile radio system, which is arranged to operate in accordance with a packet reservation multiple access protocol, wherein at least one time slot in each frame is designated for the transmission of access contention data which includes a field reserved for data specifying a number of information slots required by a mobile unit, and which system includes a base station adapted for operation such that consequent upon receipt of data in the said reserved field the base station is arranged to respond by allocating available slots to satisfy the requirement of the mobile unit.

The packet reservation multiple access protocol may be a PRMA system of the kind specified.

Since in this system the base station has a comprehensive knowledge of the current availability of information carrying slots, available slots can be allocated on the "down link" (base to mobile) in response to slot requests in the field reserved for such requests,

which requests are transmitted by the mobile unit on the "up link" (mobile to base).

As will be readily appreciated by the cognoscenti, since only one access contention request is required irrespective of the number of information slots required, the access contention time required to reserve capacity will be minimised or at least substantially reduced as compared with a system in which each individual slot must be contended for.

One embodiment of the invention will now be described by way of example only with reference to the accompanying drawings, in which;

Figure 1 is a diagram showing a PRMA protocol as used in Ref.1., as hereinbefore referred to;

Figure 2 is a diagram showing a PRMA protocol as used in Ref.2, as hereinbefore referred to;

Figure 3 is a diagram showing an information field;

Figure 4 is a diagram of a PRMA protocol for use in the present invention; and,

Figure 5 is a somewhat schematic block diagram of a mobile unit and base station in accordance with one embodiment of the present invention.

Considering firstly known systems for multiplexing multiple voice users, packet reservation multiple access (PRMA) is a multiple access protocol which first appeared in Ref.1, as hereinbefore referred to. PRMA is a technique used for multiplexing packetised digital speech or data onto a time divided carrier. It is concerned with the situation in mobile cellular radio systems in which mobile stations communicate with a base station in a given cell. In this

situation mobile stations cannot hear each other but they can hear the base station. Communication from mobile to base station is known as up-link communication whereas communication from base station to mobile is known as down-link communication.

Time division multiple access schemes may either be time division duplex or frequency division duplex. In a time division duplex scheme up and down link transmission is facilitated on the same carrier frequency by dividing the carrier by time with, for example, mobiles transmitting in a first half of the up-link frame and a base station transmitting in a second half frame on the down-link. With a frequency division multiplex scheme, the up-link and down-link are on different frequencies. A PRMA multiple access scheme will function on both frequency division duplex and time division duplex, although the following examples employ the use of a frequency division duplex scheme by way of illustration. In either case the carrier is divided into identical size frames the make-up of which is determined by the PRMA protocol in accordance with known specified parameters.

The PRMA protocol was developed so as to take advantage of the discontinuous nature of transmission of voice so as to support more voice users than there are voice channels on the time divided carrier. As such, a mobile station only accesses a voice channel whenever a period of speech or talk spurt is produced. Whenever the talk spurt is finished, the mobile releases the channel and hence inactive mobiles do not occupy capacity unnecessarily. Hence a PRMA scheme is able to improve the capacity utilisation by statistically multiplexing the voice users in a cell onto the time divided carrier.

There are principally two variants of the PRMA protocol. Both variants are described in published literature as multiple access protocols for short range communications in micro cells for example. The first variant to appear in published literature is Ref.1, as hereinbefore referred to. The operation of the protocol described in Ref.1 is herein illustrated in Figure 1 and might be described as follows. The up-link time frame is divided into a number of slots for carrying speech packets such that for an active voice one packet is required to be transmitted per frame. The down-link is divided into corresponding time slots but in addition it also has acknowledgement slots for each pair of time slots on the up and down-link frames. Whenever a talk spurt starts from a particular mobile the mobile contends for access to the channel by broadcasting an access contention burst that contains its address in any time slot in the frame. If this burst of data is received successfully by a base station then the base station re-broadcasts that mobile's address on the down-link in the corresponding acknowledgement slot. This slot is hence reserved for the mobile to broadcast until such time as the talk spurt ends in which case the slot is released and available for another mobile to access. The mobile signifies that the slot has been released in one of two ways. It either leaves the time slot empty, which is recognised by the base station as a sign that the mobile has finished with it, or it broadcasts a special end of message burst, which has the same effect.

If two or more mobiles attempt to gain access to the channel by broadcasting in the same slot the base station detects this and broadcasts a null message in the corresponding acknowledgement

slot. The mobile then backs off for a random time and re-broadcasts in another slot at random.

A key point with this PRMA variant is that the mobiles contend for access in the same time slots in which they will transmit information. Secondly, as with the protocol described in Ref.2, as hereinbefore referred to, the critical process causing delay is in gaining access to the channel through the access contention broadcast collision detection by the base station and hence re-broadcast by the mobile.

Considering now the protocol described in Ref.2, as hereinbefore referred to, this differs fundamentally from the protocol of Ref.1 because the access contention burst is broadcast in a separate time slot to that in which the information is broadcast. The essence of the protocol described in Ref.2 will now be considered with reference to the diagram as shown in Figure 2. On the up-link, two types of slots exist. There are I-slots which are used only for the transmission of information carrying bursts and R-slots where only access contention bursts are transmitted. The reservation access burst consists of the address of the mobile which is making the access contention. The mobile gains access to the channel by transmitting its access contention burst in one of the several mini slots that make up an R-slot, in one of the R slots on the up-link frame. The down-link is made up of I-slots as well as A slots. When the mobile contends for access on the up-link by transmitting its access contention, the base station replies to this on the down-link, by transmitting the I-slot number on which it should transmit its data carrying burst. The A slots follow the R-slots in time. The essence of the protocol as described in Ref.2 is that the mobile

transmits its address on the up-link in one of the mini slots that make up an R-slot in one of the R-slots. On the next A slot in the corresponding mini slot the base station broadcasts one of three types of acknowledgement packet. If the access contention request was correctly received, and an I-slot is available for transmission of an information carrier burst, then the base station sends the mobile address, together with the I-slot number on which the information is to be sent.

If the mobile's address was received correctly, but at that moment, no I-slot was available the mobile's address is transmitted on the down-link, together with an indication to wait for an information slot to come free.

If two or more mobiles broadcast their access contention bursts in the same mini slot and therefore collide, or if no air-interface channel identifier burst were broadcast on the up-link, then the base station broadcasts an idle burst.

Mobiles whose initial access is blocked by collision, back off and re-try for access contention in R-slots at random with a given probability.

It is apparent that with a PRMA scheme, in order to support variable bit rates, a user must have the ability to reserve multiple slots in any given time frame. In known systems and for example in a system using the PRMA protocol in accordance with Ref.1, a data source requiring three slots in the sub frame would require three access contentions. This would therefore increase the number of opportunities for collision and hence re-transmission and hence result in a greatly increased delay.

Similarly, if a protocol as described in Ref.2 were employed this would also require three access contentions for a user requiring three slots in a frame. If however an extra field is appended to the access contention burst, in which field the number of slots required is specified together with the mobile address, then it is possible to request from the base station directly the number of slots that are required by the mobile instantaneously. Since the base station has complete knowledge of the current availability of the information carrying slots it can allocate the mobile the available slots by signalling the mobile on the down-link. Most importantly this requires only one access contention which will therefore reduce the access contention time required to reserve the capacity required. This adapted access contention burst will hereinafter be referred to as an Air-Interface Channel Identifier (ACI). As shown in Figure 3 a typical ACI field includes data requesting a specified number of information slots, data appertaining to the address of the mobile unit and optionally a training sequence as would be required for equalization purposes in a mobile radio channel.

Since the instantaneous capacity requirements of a data source are gained through the ACI, it can be seen that an effective channel can be set up and established through the ACI only. Thus in this way there is no need to differentiate between signalling and data traffic, with both being multiplexed on to the TDMA frame. However a mobile accessing the channel for signalling information may increase the access contention priority by using a higher re-transmission probability. Hence for example asynchronous transfer mode (ATM) may be supported over the air-interface by simply mapping a VCI/VPI pair of the air-interface on to the ACI of the access protocol.

An additional problem in a large cell is the propagation delay experienced by mobiles accessing the channel. When addressing information and any additional fields of data are added, together with redundancy required for collision detection, the ACI burst will be of a similar size to the information carrying bursts. Thus the reservation capacity slot or R-slots will need to be of similar size to the information slots and then only one ACI will fit into a given R-slot. However, considering now the effect of propagation delay on the mobile broadcasting data on the channel, the first access that a mobile will make to the channel at any point in communicating with the base station will be through the access contention burst. This being so, it is unlikely that the mobile will be in the same position it was after the last talk-spurt or call. As such the ACI burst broadcast in the R-slots will be made without any timing adjustment, and therefore must include the round-trip delay propagation time. If the PRMA Ref.1 protocol were employed, then this additional propagation time would have to be made in all slots, since access contention and information broadcast are made in the same slots. However since VBR-PRMA i.e (variable bit rate) - PRMA access contention and information transfer is made in separate slots, only the R-slots need include this uncertain round-trip propagation time. Following the first access, the base station is able to measure the propagation time and signal the mobile station to advance its transmission timing so as to fit its information burst into the information slot. Thus the VBR-PRMA protocol is able to recover the capacity that would have effectively been lost with the PRMA Ref.1 protocol, since the propagation delay would be required in each time slot.

As can be seen from the diagram in Figure 4, in addition to the single I-slots, there also appear the 2 x I or double I-slots. These are required to carry speech data and information respectively. The incorporation of two possible slot sizes into the carrier sub-frame is required because of the delay constraints imposed on the transmission of voice traffic. In order to support more voice users on the air-interface, voice traffic is trans-coded to a lower bit rate. If a large burst is used to transmit data, a more efficient transport of digital information over the air-interface will result, because the non-information carrying overheads associated with transmitting each burst are of a fixed size. However for a large burst the delay incurred in waiting for enough information from a voice code would be so large as to make this delay intolerable. Hence a small burst size is required for voice traffic, at the expense of efficiency. The constraint of delay does not exist for the transport of data, in which case a larger burst size is employed so as to improve the efficiency of transport. Both single I-slots and Double I-slots are set up and positioned dynamically by the base station according to the traffic load requirements.

Automatic Repeat Request (ARQ) is a well known technique which is used to improve the error rate of a digital communications link at the expense of delay. A basic form of the technique is that an information burst having been transferred over the air-interface has some mechanism to test whether the burst has been received correctly, or has achieved a given probability of error. If the burst fails this test, then a repeat request is made and the burst is re-transmitted. There are various variants and hybrids to the basic ARQ technique.

In a VBR-PRMA scheme as herein proposed, it can be observed that in terms of the efficiency of information broadcast to the channel for signalling and control for contending for access and reserving capacity on the channel, the system will achieve greater efficiency when the channel capacity reservation is longer rather than for a shorter period. With the VBR-PRMA scheme it is proposed to support signalling and data transmission on the same channel. So as to achieve good efficiency for gaining access to the channel mentioned above, the basic packets of information on which ARQ is made are grouped into batches and transmitted over the air-interface. Any packets required for repeat request are then identified and their re-transmission requests made for the entire batch by accessing the Down-link channel. Since this requires only a single access contention per batch of bursts, as opposed to an access contention per burst, a much greater efficiency in the transport of signalling information on the air-interface will result, at the expense of some increase in delay.

To facilitate operation in a moble radio system, a protocol as shown in Figure 4, may be provided which requires the following features:

The R-slot size on which the mobile's ACI bursts are broadcast, now have a time occupancy that is of a similar size or larger than the basic I-slot. This is mainly to include a detection/correction scheme, to ensure that the ACI has a good probability of reception in a hostile radio channel, and to identify very accurately when it is received incorrectly. It also contains the information fields as shown in Fig.3.

There are no mini-bursts broadcast in the R- and A-slots, and as indicated below, the R- and A-slots are only large enough to hold a

single ACI burst as this will be broadcast without adaptive burst alighment, and so includes the maximum propagation delay.

Additionally, to support asynchronous transfer mode (ATM) operation, the following features are important.

The VPI/VCI, ie virtual path identifier/virtual channel identifier, pair of the ATM-cell is mapped on to the ACI identifier field. This therefore allows the support of signalling as well as data on the air-interface. The ACI burst therefore has a field identifying the VPI/VCI pair, and a field identifying the number of slots it requires. The second field allows the information transfer rate to be dynamically varied.

Signalling ACI's are given a higher probability of re-transmission, thus allowing them to gain access to the channel more quickly, with higher priority.

Since the protocol is to be employed in cells where the propagation delay is significant, adaptive burst alignment is employed for the transmission of data carrying bursts. As the ACI will be without adaptive burst alignment, the R slot will be large enough to incorporate the maximum propagation time envisaged for the longest range of operation. Hence by measuring the round-trip propagation delay on the ACI burst, the base station informs the mobile of this value and so adjusts it broadcast timing accordingly.

To allow low data rate, delay critical information to be carried over the air-interface a shorter information carrying burst will be used, that is broadcast in a single I-slot. To improve the data transmission efficiency, the data from the ATM-cell payload will be transmitted using a double I-slot. Hence the up and down-link frames will be made up of single and double I-slots.

To offer higher data integrity an ARQ scheme may be employed. To improve the efficiency of the ratio of information transmitted on the channel to the access contention traffic, ATM-cells are broadcast in batches. For each batch, cells received incorrectly are NACK'd, whilst if a batch is received correctly then only this is ACK'd. The ACK and NACK acknowledgements will be transmitted in the carrier frame I-slots, with channel access being performed through the ACI associated with signalling. Hence one access contention per batch as opposed to one per cell is used and therefore an improvement in efficiency is achieved.

Referring now to Fig.5, one arrangement of mobile and base station for putting the invention into effect will now be described.

Referring firstly to the mobile station the transmitter comprises a queuing buffer store 1 in which data for transmission is accumulated. The contents of the buffer is sensed by an access contention burst former 2 which determines the number of packets of data to be transmitted in a TDMA frame. Data appertaining to this number, together with the address of the mobile is fed via an address module 3 to an error correction and detection encoder 4 to a switch 5. The switch 5 is also fed from the queuing buffer 1 via a channel coding unit 6 and an interleaver buffer 7. The switch is arranged to feed an equaliser 8 and a modulator 9 which in turn feeds an aerial 10 via a transmit/receive switch11. It will be appreciated that the switch 5 is operated so that the interleaver buffer 7 is connected to the equaliser 8 for the transmission of data during an appropriate time slot or so that the error correction and detection decoder 4 is connected to the equaliser 8 for the transmission of access contention data appertaining to the number of

packets of information to be transmitted. Receive signals are fed via the switch 11 to a demodulator12 which feeds the detector 13. The detector 13 either feeds a data reception chain 14 via a switch 15 or an acknowledgement burst error control decoder unit 16 and a slot transmission timer17 which serve to identify available slots during which data packets in the queuing buffer 1 should be transmitted.

The base station comprises a transmit/receive aerial 18 fed for transmission purposes from a modulator19. Signals received at the aerial 18 are fed via a detector 21 and demodulator 22 to a data reception chain 23 via a switch 24. The switch 24 is arranged to feed the data reception chain 23 for data reception purposes or an access burst error correction and detection unit 25 when access-contention request data is received. The access burst error correction and detection unit 25 feeds a packet reservation multiple access control algorithm unit 26 which analyses each access contention request and serves to provide data appertaining to available time slots, which data is fed via an acknowledgement burst former 27 to an address unit 28 which serves to add the mobile's address to the data and an error correction and detection decoder 29 for the acknowledgement burst. The modulator 19 is fed conventionally with data during appropriate transmission slots and from the error correction and detection decoder 29 for the transmission of acknowledgement signals and data appertaining to slots in which a mobile should transmit. In order to highlight novel features of the arrangement just before described with reference to figure 5 those units which are novel and additional to a known system are shown in the shaded regions 30 and 31 for the mobile station transmitter/receiver and the base station transmitter/receiver respectively. Various

modifications may be made to the arrangement shown without departing from the scope of the invention and for example the equalizer 8 and or the interleaver buffer 7 may be omitted.

CLAIMS

1. A cellular mobile radio system, which is arranged to operate in accordance with a packet reservation multiple access protocol, wherein at least one time slot in each frame is designated for the transmission of access contention data which includes a field reserved for data specifying a number of information slots required by a mobile unit, and which system includes a base station adapted for operation such that consequent upon receipt of data in the said reserved field the base station is arranged to respond by allocating available slots to satisfy the requirement of the mobile unit.

2. A cellular mobile radio system as claimed in Claim 1 which operates in accordance with a PRMA protocol of the kind as herein before specified.

3. A system as claimed in Claim 1 or Claim 2, wherein consequent upon receipt of data in the said field, the base station responds to the mobile unit by transmitting timing information derived in dependence upon the time of arrival of the said data, which timing information is utilized by the mobile unit to adjust the timing of the next transmission burst of data so that the burst is fitted in an appropriate designated slot, whereby the effects of propagation delays are compensated for.

4. A system as claimed in any preceding claim, wherein slot duration is adapted in dependence of the character of data to be transmitted, such that a relatively shorter slot is assigned for the

transmission of small packets of information and a relatively longer slot is assigned for the transmission of larger packets of information.

5. A system as claimed in Claim 4, wherein two slot widths are provided for small and large packets of information respectively.

6. A system as claimed in any preceding claim, wherein asynchronous transfer mode (ATM) cells are batched for the transmission of data, the system including an automatic repeat request (ARQ) facility, whereby repeat requests are made in respect of only those cells of a batch which are errored, as indicated by an error detector, forming a part of the ARQ system.

7. A system as claimed in Claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17 (The Search Report)

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Relevant Technical fields

(i) UK Cl (Edition K) H4K: KYA; KYR; KYX

(ii) Int Cl (Edition 5) H04Q

Search Examiner
ALAN STRAYTON

Databases (see over)

(i) UK Patent Office

(ii) ONLINE: WPI

Date of Search
25 NOVEMBER 1992

Documents considered relevant following a search in respect of claims ALL

Category (see over)	Identity of document and relevant passages	Relevant to claim(s)
	NONE	

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

X: Document indicating lack of novelty or of inventive step.

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&: Member of the same patent family, corresponding document.

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